Environmental Science and Policy 96 (2019) 37–51

Contents lists available at ScienceDirect

Environmental Science and Policy

journal homepage: www.elsevier.com/locate/envsci

Effective scaling of climate smart agriculture innovations in African smallholder agriculture: A review of approaches, policy and institutional strategy needs

Clifton Makate

Africa Centre of Excellence (ACE) for Climate Smart Agriculture and Biodiversity Conservation (Climate SABC), Haramaya University, P.O. Box 138, Dire Dawa, Ethiopia

ARTICLE INFO

Keywords:
Policy & institutional actions
Scaling up and out
Climate smart agriculture
Smallholder farmers
Review
Climate change

ABSTRACT

Climate variability and change is a major source of risk to smallholder farmers in Africa. Climate related risks are linked to low productivity, food insecurity and poverty. However, the research and development community is widely promoting Climate-Smart Agriculture (CSA) to transform livelihoods under a changing environment. To date, adoption of CSA practices is low across Africa despite their demonstrated effectiveness. The low adoption challenge calls for prudent policy and institutional efforts in finding ways to effectively take CSA practices to scale. CSA scaling (upgrading) is the expansion of the adoption of the proven and beneficial CSA practices and/or technologies. This article is guided by the Institutional Analysis and Development framework to review current literature and weigh possible approaches/strategies, policy actions and institutional needs that can promote the upscaling of CSA technologies among smallholder farming communities. Various methodologies, policy actions, institutional strategy focal issues and possible determinants of scaling success are discussed. The article concludes that scaling of CSA practices, and technologies is not autonomous, there is need for facilitation in terms of conducive policy and institutional actions. Policy strategies are important as they clearly define the rules of the game that will ultimately establish responsibilities in the scaling process by stakeholders. Effective and complementary institutional actions towards scaling can minimize farmer challenges, reduce adoption constraints, and improve sustainability in scaling processes, which can ultimately improve impacts of CSA practices and technologies to society.

1. Why climate smart agriculture?

Climate change and variability is an incremental modern day threat to agricultural production, food security and livelihoods for millions of people all over the world (IPCC, 2014). Climatic change especially through increased temperatures, dynamic rainfall patterns, and variations in intensity and frequency of extreme events such as droughts and floods, significantly limits agricultural production to varying degrees in different regions of the world (Aggarwal et al., 2009; Brida and Owiyo, 2013; FAO, 2018; IPCC, 2014; Lobell et al., 2012; Zseleczky and Yosef, 2014). According to Porter et al. (2014), estimated negative impacts of climate change on cereal crop yields in different regions indicate up to 60% reduction in maize yield, 50% yield reduction for sorghum, 35% yield reduction for rice, 20% reduction for wheat and 13% reduction for barley. For sub Saharan Africa (SSA), climate variability and change is predicted to continue decreasing production of major cereal crops in the region including maize, sorghum and millet. Maize, sorghum and millet yields are estimated to fall by 22, 17 and 17% respectively by 2050 (IPCC, 2007, 2014; Schlenker and Lobell, 2010). More so, rain-fed crop yields are also projected to decrease by almost 50% due to climate variability and change. With a rise in average global temperature beyond the 1.5 °C threshold almost inevitable (Nkemelang et al., 2018; Schleussner et al., 2016), these impacts could be worse, with chances of total crop failure expected especially in semi-arid landscapes.

Negative impacts of climate change on crop production can translate to food insecurity, lower standards of living, reduced well-being and general poverty. The available evidence suggests that the impact of climate-related disasters are much worse in developing regions such as Sub-Sahara Africa (SSA) and even worse for poorer individual communities and households in developing regions e.g. among smallholder farmers (Carter et al., 2007; Gaiha and Thapa, 2006). Climate change and variability affects food security through its influence on production and incomes of farmers which then inhibits food availability, access, utilization and stabilization (FAO, 2010, 2013, 2018). More so, climate change and variability can even worsen the livelihoods of people through increased poverty. First, according to Barrett and Swallow

E-mail address: ruumakate@live.com.

https://doi.org/10.1016/j.envsci.2019.01.014
Received 24 August 2018; Received in revised form 11 January 2019; Accepted 27 January 2019
Available online 07 March 2019
1462-9011/

(2006) and Carter and Barrett (2006) at aggregate level, climate risk can constrain economic opportunities and hence reinforce poverty and the potential for poverty traps at the household level. Second, climate shocks can exacerbate poverty through: (i) discouraging asset accumulation and reducing profitability and productivity of existing assets as households are forced to use their assets in ex-ante climate risk management, (ii) diversion of productive assets by non-poor but vulnerable household through ex-post coping responses to recurrent and severe climate shocks, and the general higher opportunity cost of climate for poorer households (i.e. climate risk tolerance tend to decrease with decreasing resource endowments) (Carter and Barrett, 2006; Hansen et al., 2018).

These adverse impacts associated with climate change signify the need for agricultural production to adapt to the ever-changing climatic patterns or seasons, in order to minimise the likely adverse effects that ensue such as low food production and income levels. Adaptation in agriculture can restore hope for improving food security, incomes, reducing poverty and safeguarding human well-being under a changing and variable climate especially in developing countries in SSA. For SSA, building resilience of smallholder farmers (main food producers in the region) is increasingly becoming a priority for policy (Zseleczky and Yosef, 2014) and to date, a number of countries have incorporated climate adaptation and mitigation practices into their national policy documents.

Climate-Smart Agriculture (CSA) is being promoted widely to transform agriculture under a changing climate (FAO, 2013; Hansen et al., 2018; Nkonya et al., 2018). By definition, CSA is an approach that aims to transform agricultural systems and support food security under changing climate through providing context-specific, socially acceptable and flexible solutions (Lipper et al., 2014). The CSA approach works on three basic tenets: (i) increasing agricultural productivity in a sustainable way, supporting equitable improvements in farm income, food security and development, (ii) reinforcing the resilience of agricultural and food systems to climate variability and change, and (iii) reducing net greenhouse emissions from agricultural activities (crop, livestock, fisheries etc.) (Lipper et al., 2014; McCarthy and Brubaker, 2014). A number of agricultural production technologies and practices fall under CSA including stress-adapted crop and livestock breeds, improved water management technologies (e.g. small-scale irrigation), agroforestry and conservation agriculture, crop diversification, index-based insurance, integrated soil fertility management practices (e.g. mulching and rotations) and others. (see FAO (2013) for more).

Emerging studies show that, as an approach, CSA can positively influence livelihoods, biodiversity and food security under a changing climate. A number of CSA practices have been proven to improve productivity, incomes and food security in different areas. For instance, literature shows that: (i) adoption of stress-adapted crop varieties improve yields, farmer incomes and food security (Lunduka et al., 2017; Makate et al., 2017b; Masuka et al., 2017; Setimela et al., 2017a, b), (ii) diversification of farming systems improve crop and livestock yields and other livelihood benefits (Makate et al., 2016; Matsuda, 2013; Megersa et al., 2014), (iii) adoption and use of conservation farming enhances yields and livelihood (Kiboi et al., 2017; Mango et al., 2017; Michler et al., 2016), and (iv) adoption of agroforestry practices is highly associated with improved incomes, livestock holdings and better overall household nutrition (Bostedt et al., 2016; Thorlakson and Neufeldt, 2012).

The positive impacts of various CSA practices are a welcome development for agricultural progress under increasing climate stress. However, CSA can only have significant overall impacts on society if associated practices are adopted at scale. In other words, the lasting impacts of CSA especially among the poor can only be realised if efforts are strengthened at the institutional level, more farmers adopt these practices, and that current adopters intensify the adoption of such practices. However, the uptake of CSA practices in low-income regions such as in SSA is still considered low or unsatisfactory (Campbell et al., 2014; Thornton and Herrero, 2010; Westermann et al., 2015) particularly in SSA region (Arslan et al., 2014; FAO, 2018; Makate et al., 2017a; Ringler and Nkonya, 2012; Teklewold et al., 2013). In the emerging literature, low adoption rates are mostly attributed to a number of factors including lack of evidence or success stories on the practicality of incorporating the various CSA approaches and technologies into agricultural systems (Aggarwal et al., 2018). In addition, donor dependency (collapsing of CSA initiatives after donor funding dries up), weak institutional set-up (e.g. extension systems) and lack of supportive policies and policy strategies for CSA are some of the factors that affect scaling of agricultural innovations (see Hatmann and Linn (2008) and Ajayi et al. (2018)). As noted in Steenwerth et al. (2014), effective scaling of CSA requires an integrated approach in which science, technology and decision making interact with local socio-economic conditions and cultures.

Against the above background, this study therefore aims to contribute to the current discussions around enhancing the uptake of CSA practices by identifying institutional and policy strategies that promote the eventual scaling of these practices in developing countries particularly in SSA. Institutional and policy actions are critically important for CSA scaling efforts. For instance, improving policy and institutional support for farmers in accessing CSA technologies, key agricultural inputs, agricultural advisory services, finance, and viable markets, among other things, can improve CSA upgrading (scaling) at both farm and landscape level mainly through increasing demand for the technologies.

2. Objectives, rationale and organization of article

This study aims to contribute to literature on CSA scaling by identifying institutional and policy strategies that can help effect scaling of CSA practices in developing regions particularly SSA region. Increased adoption rates are more likely to enhance the overall impact of CSA innovations on productivity, food security, livelihoods and overall sustainability of agriculture. Furthermore, the study seeks to highlight and suggest possible approaches/strategies that the research and development community can adopt in taking CSA to scale. In the process, the review also aims to draw lessons on some of the key factors that can ensure success and sustainability of CSA scaling efforts in the SSA region.

Scaling in this study is considered a process or processes that lead to introduction of CSA technologies with demonstrated effectiveness through a program delivery structure particularly aiming to improve coverage and equitable access to the CSA innovation(s) and realization of improved social, economic and environmental benefits. The definition is adapted from IIRR (2000) who defined scaling up as efforts to bring more quality benefits to more people over a wider geographical area more quickly, equitably and that such benefits have a lasting impact. Both horizontal and vertical scaling up and out are considered (details of scaling theory is highlighted in Section 5). Horizontal scaling up (also known as scaling out or adoption) basically involves a proven CSA technology reaching more people and communities. Vertical scaling up (also known as institutionalization) however, entails making decisions at higher level and basically involves expanding CSA technologies beyond the original participants and objectives, also taking cognisance of the scope of interventions, quality of impacts and the sustainability issues. For simplicity, the study uses the words "scaling" and "upgrading" interchangeably to refer to all forms of scaling (vertical and or horizontal scaling up and out).

The study is motivated by the urgent need for adoption of various CSA technologies particularly in poorer communities in SSA – a region amongst those critically impacted by climate variability and change. Research activities have devised robust CSA technologies which have been proved to offer effective adaptation and mitigation co-benefits in agriculture (FAO, 2018; Hansen et al., 2018) However, as noted earlier, adoption rates are still reported to be very low across Africa. A number

of CSA practices are targeted to mitigate climate variability risk and foster resilience in smallholder farming systems of SSA, including diversification (crop, livestock, income), stress tolerant crop and animal species, index-based insurance, conservation agriculture, agroforestry just to give a few examples (FAO, 2018; Hansen et al., 2018). Effective scaling strategies at policy and institutional level can improve adoption of the various CSA technologies. Unravelling some policy and institutional focal areas, possible strategies that can be used including the success and sustainability factors to watch for under effective scaling/upgrading of CSA is the main motivation of this article. This paper considers scaling issues that can suit the CSA field in SSA but adapt lessons from scaling projects in both developed and developing countries to build arguments presented in this article. For a systematic presentation of arguments, the study adapted the Institutional Analysis and Development (IAD) framework presented and justified in Section 3.

The rest of the article is organized as follows: Section 3 discusses the conceptual framework adapted in presenting arguments in this article whilst Section 4 presents the method followed in selecting literature. Sections 5 and 6 present the scaling theory with regards to agricultural development interventions and possible scaling approaches (strategies) that can be used to take CSA practices and technologies to scale respectively. Section 7 highlights some of the commonly noted success and sustainability factors in scaling agricultural interventions like CSA from literature. Section 8 presents policy and institutional focal areas and strategies that are instrumental in effecting upgrading of CSA practices in smallholder agriculture. Finally, Section 9 presents the review summary, conclusions and recommendations.

3. Conceptual framework: institutional analysis and development framework

The study adapts the institutional analysis and development (IAD) framework by Ostrom et al. (1994) to evaluate possible policy and institutional actions, approaches/strategies that research and development partners can adapt in improving scaling CSA technologies of demonstrated effectiveness in smallholder farming. The IAD framework was chosen because of its merit in providing a simple framework for analyzing institutional and policy actions in terms of how they can influence initial conditions of subjects (e.g. smallholder farmers) and actions by various stakeholders interested in improving initial conditions of subjects (e.g. research and development community aiming to upgrade CSA in SSA) and hence eventual outcomes (e.g. more farmers adopting and receiving more quality benefits from CSA). In this context, the IAD framework was used to analyze how and why policy and institutional actions can affect smallholder farmer situations (i.e. access to resources, enhancing their knowledge, improving institutional credit and extension access etc.) for eventual improvement in CSA practices upgrading (scaling). However, selecting potential approaches and noting success and sustainability factors in CSA upgrading were not directly informed by the IAD framework. Instead, understanding some parts of the IAD framework, for instance, initial conditions (community attributes, farmer wealth, and informal and formal rules used in their locality) helped in suggesting CSA scaling approaches/strategies that can be used and/or what can be done to enhance success and sustainability of CSA scaling actions. Previous studies have also adapted the IAD framework in closely related research (see for example Raheem (2014) and Nigussie et al. (2018)).

The IAD framework include three main pillars; “initial conditions”, “action arena” and “outcomes” (Fig. 1). The “initial conditions” comprise biophysical conditions on the smallholder farm, farmer asset conditions and wider community attributes in which the farmer works or operates in. In addition, they also include the political and legal system as well as the informal rules and norms in which the smallholder farmer operates. “Initial conditions” have an effect on intended outcomes (CSA scaling success) hence they are an important component to consider. "Initial conditions” therefore include assets as one element which may include both tangible and intangible assets that the smallholder farmer possess, use, mobilize and exchange with other players. The tangible assets include those they put into action directly including human, financial, and capital assets. Intangible assets include access to information, and social capital/networks just mentioning a few examples. Asset conditions are important as they can influence CSA technology adoption. Most CSA technologies require extra resources and asset conditions hence the farmer can potentially tell which CSA technologies to adopt or not adopt. “Community attributes” in which different farmers are operating are equally important to consider. Precisely, community attributes are important in differentiating smallholder farmers across a wider spatial scale. Like asset conditions, community attributes are important as they can reveal which CSA technologies can be socially acceptable in a particular community and hence they should be reflected. Also included in the “initial conditions” are the legal and political systems that may affect the activities of the smallholder farmer. Political and institutional factors can influence CSA investments or other complementary investments important for CSA at the farm level and hence scaling outcomes and therefore important to consider. For instance, nature of property rights on land can influence CSA adoption choice at farm level hence it is imperative for stakeholders to consider them for effective choice of scaling strategies. Also, political will by local leaders can, to a large extent, impact on CSA scaling success.

“Action arena”-All the initial conditions highlighted earlier will define the action environment. The initial conditions affect the “action arena” which is the space where all stakeholders interact (fight, negotiate, work together) in order to get intended scaling actions for set intended outcomes.

“Outcomes”-Lastly, the outcome(s) includes the final product (success) for the actor and or the wider society. In this study, the outcome of interest is CSA scaling success (more quality benefits from CSA to wider society). The whole process (framework) is iterative and has feedback mechanisms. For instance, poor outcomes can lead to a change in rules in use which can also influence the action arena. More so, desired outcomes i.e. quality benefits of CSA received by wider society, can also have an important feedback on the initial conditions such as reinforcing current laws, improving the asset base for even better outcomes.

4. Selection of literature

The article reviewed recently published literature to come up with a comprehensive analysis of possible methods/strategies, policy and institutional strategies that can be adopted in smallholder African agriculture to take climate-smart innovations to scale. The study considered strategies that can help in scaling CSA practices such as stress-adapted crop and livestock germplasm, improved water management technologies e.g. small-scale irrigation, agroforestry, conservation agriculture, crop diversification, agricultural insurance, integrated soil fertility management practices (e.g. mulching, rotations) and other related CSA practices.

The analysis considered literature from articles, chapters and books published in English and mostly published in the 21 st century. Contestant publications were identified through a combination of the author’s familiarity with the research theme’s literature, review objectives and the study conceptual framework. Literature searched and evaluated mainly falls in the categories of: (i) adoption and impacts of climate smart agricultural technologies/practices/innovations, (ii) technologies/innovation scaling theory, (iii) approaches/strategies for taking technologies and their impacts to scale, (iv) factors and strategies for successful technology scaling, and (iv) policy and institutional interventions necessary for scaling agricultural technologies/practices. Studies mainly from the developing world (Africa, Asia and Latin America) and a few from the developing world were considered in gathering literature. Key word searches with Google Scholar, guided by the main aforementioned categories, and forward searches of

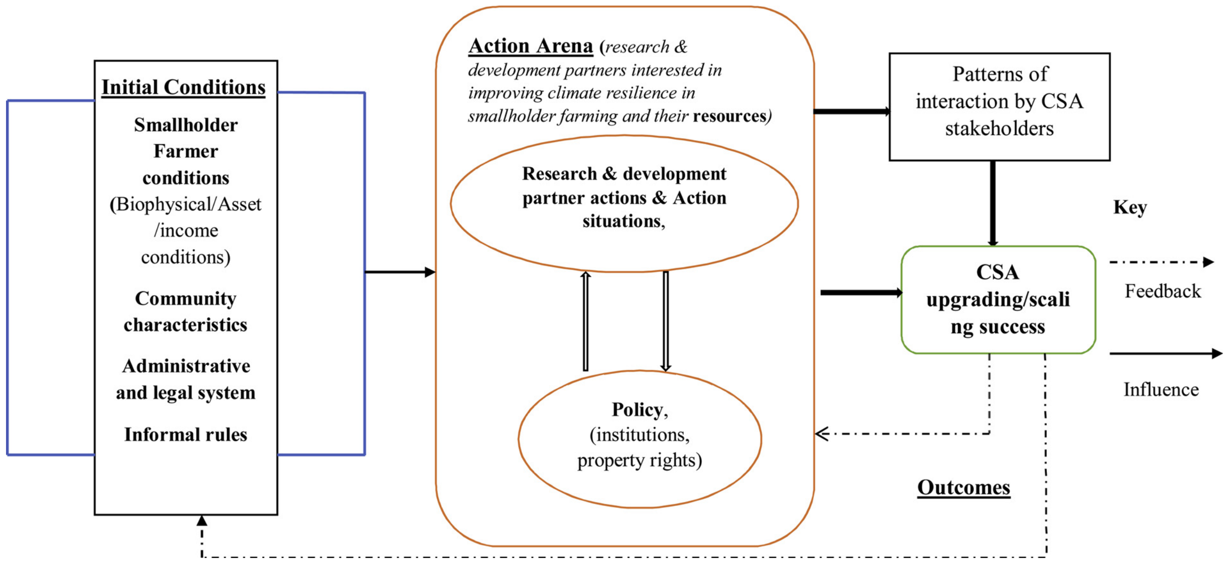

Fig. 1. Framework of analysis adapted from Ostrom, Gardner, Walker, and Walker (1994).

publications that cited relevant literature helped in gathering 235 candidate publications. However, only 135 publications from the 235 pre-selected literature sources qualified for the analysis and were included in this review. All literature cited in this review were accessed and read. Summary details on the final list of literature source types used in writing this review article are shown in Appendix A.

5. Scaling agricultural technologies: theory

This sub-section briefly reviews important theoretical footings on the meaning of scaling and related concepts. Briefly discussed under this sub-section include (i) Scale as a concept and possible misconceptions, (ii) distinguishing scaling UP and scaling OUT, and (iii) scaling typologies.

5.1. Scale as a concept and possible misconceptions

Scaling agricultural technologies is more of a management issue (Pachico and Fujisaka, 2004) than science. In this sense, scaling agricultural technologies is concerned about the management of projects to ensure that positive impacts are maximised and that impacts are sustainable and equitable. Scaling is also understood better in terms of hierarchy of levels of analysis (Pachico and Fujisaka, 2004; Swallow et al., 2002; Wigboldus and Leeuwis, 2013). Important to note is the fact that research outcomes are usually dependent on the scale at which the analysis was done (Pachico and Fujisaka, 2004). Scale may be defined along lines of different ways of ordering e.g. spatial scales (locality, landscape, region or globe), temporal scales (daily, seasonal, annual, decades, centuries), jurisdictional/geographical scales (local, municipal, regional, national, international), economic scales (poor, medium-income, rich), social scales (individual, group, community, country), project scales (input, activity, output, outcome, impact), knowledge scales (specific to general), organizational scales (micro, meso, macro) (Gillespie, 2004).

According to Swallow et al. (2002), two types of fallacies are common in conceptualizing scale namely: (i) composition fallacy which is basically based on the notion that what is good for one individual is good for everyone and (ii) the ecological fallacy which assumes that what work at one scale will work at another. An example of a composition fallacy in scaling CSA technologies would be to assume that if one district or village increases income by adopting stress-tolerant maize variety, all villages or districts in the country could do the same. The case may not be the same for other villages and/or districts as the resulting production of maize may be a fall in maize prices which would rather reduce income from production. An exception will be the case when there is a big market for the maize crop. Swallow et al. (2002) gave an ecological fallacy example of extrapolating subplot-level soil erosion data to the watershed level. Given that most soils move only a short distance and/or may have its movement interrupted by a variety of physical or biological structures in the landscape, it may take a very long time for it to reach streams or other areas where it could potentially cause harm. It therefore implies that a multi-scale analysis is always needed to support the processes of scaling up use of technologies and their impacts (Ajayi et al., 2018; Pachico and Fujisaka, 2004; Snapp and Heong, 2003; Swallow et al., 2002).

5.2. Distinguishing scaling UP and OUT

The terms scaling up and out have been used interchangeably to mean the same thing in literature with scaling up being the most commonly used term (Ajayi et al., 2018; Wigboldus and Leeuwis, 2013). However, Wigboldus and Leeuwis (2013) distinguished scaling up and out and defined scaling out as referring to quantity (reaching more people) whilst scaling up refers to quality (properties) (i.e. quality of intervention processes and outcomes). It therefore implies that, depending on the object of scaling, scaling out will mean replication, copy-paste, more of the same, expansion, extension, adoption, dissemination, transfer of technology, mainstreaming, roll-out or multiplication whilst, scaling up will mean transition, institutionalization, transformation, integration, incorporation, evolution and or development (Wigboldus and Leeuwis, 2013).

The diagram in Fig. 2 demonstrates what scaling out and scaling up is using two different illustrations. As illustrated by Wigboldus and Leeuwis (2013) scaling out processes will be different at different levels. For instance, In biological terms, scaling out may be analogous to vegetative reproduction (maintaining the same attributes in scaling), while scaling up may be considered equivalent to generative reproduction (which lead to new attributes) (Wigboldus and Leeuwis, 2013). This is well illustrated in the two examples given in Fig. 2.

5.3. Scaling UP typologies

5.3.1. Scaling UP typology by non-governmental organizations

In literature, and as stated earlier, the word scaling up is generally used as an all-encompassing term to refer to a combination of different processes, which themselves have different definitions (Pachico and

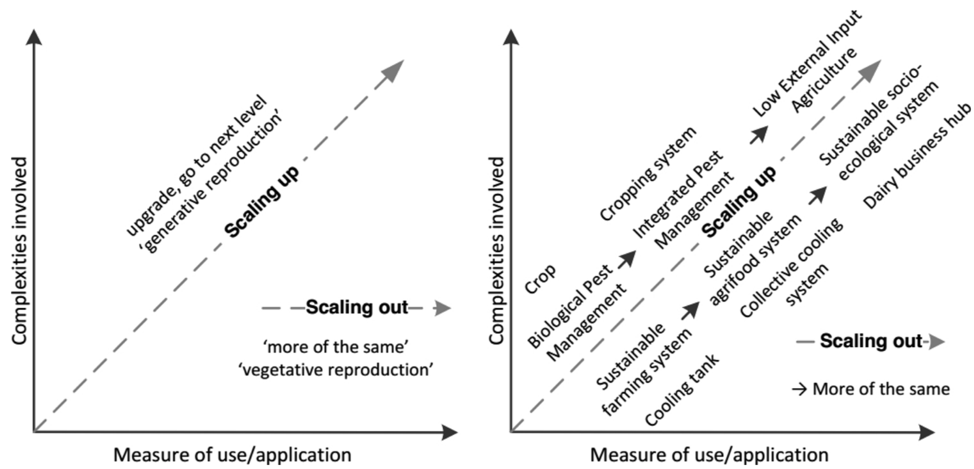

Fig. 2. The difference between scaling up and scaling out by Wigboldus and Leeuwis (2013).

Table 1
Typology of scaling up by Non-Governmental Organizations.

Type	Description	Alternative terms
Functional scaling-up	Projects and programs expand the type of activities (e.g., from agricultural intervention to health, credit, training, etc.)	Vertical scaling up
Political scaling-up	Projects/programs move beyond service delivery, and towards change in structural/institutional changes	Vertical scaling up, institutionalization
Quantitative scaling-up	Expansion or growth in their basic meaning: increase the number of people involved through replication of interventions, activities and experiences.	Scaling out, horizontal scaling up
Organizational scaling-up	Organizations improve their effectiveness and efficiency to allow for growth and sustainability of interventions achieved through increasing staff training, financial resources, networking etc.	Institutional development, vertical scaling up.

Adapted from; Gundel et al. (2001) and Pachico and Fujisaka (2004).

Fujisaka, 2004). Scaling work on Non-Governmental Organizations (NGOs) by Uvin (1995) defined four types of scaling up which are; functional, political, quantitative and organizational. The descriptions and definitions are shown in Table 1:

The typology relates with the horizontal versus vertical scaling typology which is briefly discussed in the next sub-section.

5.3.2. Vertical vs horizontal scaling

Another typology of scaling which is widely used in literature distinguishes scaling types as follows: vertical scaling up and horizontal scaling up as agreed by workshop participants at the "Going to scale" workshop hosted by the International Institute of Rural Reconstruction (IIRR) (IIRR, 2000). This typology has been widely used in literature (see (Ajayi et al., 2018; Edwards, 2010; Gundel et al., 2001)) and this analysis also adopted the same definitional dimensions. According to Wigboldus and Leeuwis (2013), vertical scaling relates to crossing scale levels, whilst horizontal scaling relates to staying within a particular scale level. More on the two typologies is discussed below with some examples given.

a) Vertical scaling up:
As defined by IIRR (2000) vertical scaling up is going higher up the ladder. It is institutional in nature and involves other stakeholder groups in the process of expansion from the grass-roots organizations to policy makers, donors, investors, and development institutions at the international levels (Pachico and Fujisaka, 2004). It therefore implies that, vertical scaling up may mean moving from individual to collective decision making, or it may involve moving from simple organizations based on face-to-face interaction to complex, hierarchical organizations. An example of vertical scaling can be when one CSA technology such as a drought tolerant bean variety goes from being used by individual farmers to being used in a coordinated way by a group of farmers in the same community, or by an association of farmer groups in many communities. Vertical scaling up also includes institutionalization which is often referred to as mainstreaming, especially in the participatory literature (IIRR, 2000; Pachico and Fujisaka, 2004; Wigboldus and Leeuwis, 2013). This implies getting institutions to accept and internalize underlying principles of an innovation (CSA innovation in this case) so that these will remain as guiding principles of future practices even after the initial innovative program or project ceases.
b) Horizontal scaling up:
On the contrary, horizontal scaling up is geographically spread to cover or include more people and communities through simple replication and adaptation, and it involves expansion within the same sector or shareholder group (IIRR, 2000; Pachico and Fujisaka, 2004). Decision making is done at the same social scale. Horizontal scaling up is also known as scaling out. An example of horizontal scaling up could be the adoption by more people in the same community or spread to different communities of agroforestry and conservation farming practices as adaptation to climate variability and change. Horizontal scaling up requires adapting knowledge and innovations to conditions of different end-users, which requires more understanding of the principles underlying an innovation.

As a recommendation, and for this to be done successfully, those responsible for doing the scaling out (either farmers or extension workers) will need more training and support networks in order to work well with communities and adapt innovations to their wants. Differences and connection between horizontal/vertical scaling and scaling up/out are shown in Table 2, with some examples.

Overall, from the illustrations and examples given in Table 2, it can be concluded that vertical scaling adds a layer of complexity to the scaling process and involves more uncertainty in terms of outcomes of scaling processes than horizontal scaling.

This study, as highlighted before, learns from the scaling theory and therefore defines CSA scaling or upgrading as a process or processes that lead to introduction of CSA technologies with demonstrated

Table 2
Understanding the difference and the connection between scaling up/out and horizontal/vertical.

	Scaling up	Scaling out
Vertical scaling	Innovation/development (institutional/technological/etc.) towards different scale levels (e.g. from local fresh vegetable business hub to national fresh food system, or from local regulatory framework to national policy.	Multiplication towards different scale levels (e.g. extension processes, or policy adoption of local practice towards country-wide application).
Horizontal scaling	Innovation/development (institutional/technological/ etc.) at the same scale level (e.g. from local cooling system to local fresh vegetable business hub, or from local regulation to local regulatory framework.	Multiplication at the same level (i.e. spreading processes, such as wider adoption of CSA technologies or of an institutional arrangement within the same village or district

Adapted from Wigboldus and Leeuwis (2013).

effectiveness through a program delivery structure particularly aiming to improve coverage and equitable access to the CSA technology(ies) and realization of quality social, economic and environmental benefits.

6. Possible approaches/strategies for scaling CSA in smallholder farming

From literature, a number of approaches or strategies have been found to work in brining innovative technologies to scale in agriculture. Some of the approaches to be discussed in this section include: value chain development approach, innovation platform approach, social movement approach, climate smart village approach, cooperatives, market driven approaches, and other participatory approaches (i.e. community based scaling approaches). The same approaches can be used to take CSA innovations to scale in smallholder agriculture. However, strategies within the proposed approaches may overlap and not all approaches will work in different smallholder farming conditions. As always, necessary adaptations of approaches are required for them to fit specific localised social, economic, cultural, and environmental conditions as discussed under the IAD framework. Specific community, farmer attributes, local administrative systems and local norms will help determine specific actions that can work in their particular locality. Important to note however, is the fact that using a combination of the proposed approaches, depending on feasibility and context, can yield more effective outcomes. Suggested approaches are mostly bottom-up and participatory approaches and hence may overlap. However, they have different theoretical constructs which may give them different pros and cons in application hence making it necessary to consider each and every one of them here. More so, deliberate focus is put on participatory approaches due to the nature of the subject (scaling) it involves multiple stakeholder actions.

6.1. Value chain development approach

This approach entails spreading of CSA technologies through value chain upgrading and development. For instance, stress-tolerant crop germplasm can significantly upgrade crop value chains even when faced with climate stress. Hence, commercializing such technologies helps increase demand for them, and this may ultimately lead to their greater adoption in societies with the same problem (climate-stress). More so, a well-defined value chain can highlight all the necessary actions, stakeholders, policy and institutional strategies needed for scaling impact of value chain upgrading technologies (USAID, 2014). Also, according to Ajayi et al. (2018), using value chain development in scaling agricultural development interventions is effective in that it ensures that all key actors along a certain product value chain are sensitized and empowered in performing their functions and in receiving their rewards on time, money and energy investments. It therefore means that upgrading agricultural value chains, specific crop or livestock value chains or the overall chains (involving all agricultural products), can effectively help in the scaling of CSA technologies through raising demand of CSA innovations in smallholder farming value chains. As the main aim of value chain upgrading and development will be to improve competitiveness, smallholder farmers, as one of the agricultural value chain actors, will seek to protect their agricultural production from climate shocks. As a result, they end up adopting well demonstrated and effective CSA technologies that adapt their production practices to the ever-changing environment. Another instance considering agro-dealers, they can also respond by intensifying distribution (through selling) of demonstrated drought-tolerant crop varieties. This will ultimately, improve adoption of the technology in a particular district, province and country. CSA technologies with functional markets are more likely to be scaled effectively through this approach. The approach will however bank on effective participatory actions by all value chain actors for to enhance scaling success.

6.2. Market driven approaches

Related to the value development chain approach, the facilitation of access to markets and market information with an agricultural commercialization motive can help scaling CSA innovations. Since markets are increasingly becoming key drivers of agricultural development (Ajayi et al., 2018; Fischer and Qaim, 2012), improved access to market and market information can increase demand for agricultural technologies, including CSA innovations which can eventually promote their scaling up. This is mainly because access to markets and market information improves consumption which through positive feedback mechanisms drives production of goods and services. More so, for some CSA innovations that are mainly accessed by farmers through the market system i.e. drought tolerant crop and livestock germplasm, well developed market systems for such technologies can enhance their adoption. It therefore implies that, scaling up CSA technologies can be informed by market opportunities of what they produce, the technologies themselves (potential livelihood impacts) and their accessibility through the market system (for those distributed through the market system). The distinctness of market driven approaches to value chain development approaches is that market driven approaches only target market development to increase demand for CSA practices/technologies. However, value chain development approaches target development of all value chain stages (research, input procurement, production, processing and consumption) in addition to the market to increase demand for CSA technologies. It therefore means the value chain development approach can be more appropriate in promoting scaling success of CSA innovations (in general) as it focus on improving all value chain stages (including the market). However, for specific CSA technologies (e.g. stress adapted seed) that have a well-developed market, the market driven approaches can be more appropriate.

6.3. Cooperatives approach

Cooperatives are basically private organizations owned and controlled by people who use its outcomes, supplies or services. Cooperatives vary in type and membership size, but are basically formed to meet specific objectives of their members and are structured to adapt their changing needs (Centner, 1988; Valentinov, 2007). Cooperatives in agriculture can serve members in production, marketing, input procurement, labour and farm management, among other needs. With increased crop production risk due to climate variability and

change, cooperatives in agriculture can be good advocates in promoting horizontal scaling of CSA innovations. This will be done to ensure that livelihoods of people it serve are not jeopardized because of the risk. Besides, studies have generally linked agricultural cooperatives with improved technology adoption and impacts (Abebaw and Haile, 2013; Fischer and Qaim, 2012; Francesconi and Heerink, 2011; Ito et al., 2012; Verhofstadt and Maertens, 2014). In different parts of Africa, cooperatives have been found to influence horizontal up-scaling (adoption). For instance, cooperatives have been found to improve; adoption of mineral fertilizers, improved seed and pesticides in Rwanda (Verhofstadt and Maertens, 2014) and fertilizer adoption in Ethiopia (Abebaw and Haile, 2013). More so, cooperatives have been reported to improve household welfare in China (Ito et al., 2012; Wanglin and Awudu, 2015). This implies that, farmer cooperatives can be a useful strategy for taking CSA innovations to scale in smallholder agriculture. Cooperatives will bank on resource pooling (e.g. capital, knowledge, technology, land etc.) to enhance success of their endeavours including greater adoption and impacts from technologies. The action arena is more functional when stakeholders involved in CSA scaling bring more resources (capital, knowhow, etc.) on the table. As opposed to individual actions, participatory actions from cooperation improve CSA scaling due to the availability of resources.

6.4. Innovation platform approach

The innovation platform approach is a participatory approach to agricultural development (Adekunle et al., 2016, 2009) that can help take agricultural technologies to scale. In this approach, key partners or stakeholders in scaling up are mobilised and brought on-board (action arena) to interact and participate in objective setting, problem identification, solution identification and mainstreaming, selection and prioritization of technologies to be taken to scale for eventual improvement to society (Ajayi et al., 2018; Jonasova and Cooke, 2012). The model banks on well-established partnerships for effective scaling of technologies in agriculture. Theory and practice of the approach is well articulated in Adekunle et al. (2009); Adekunle and Fatunbi (2012) and Fatunbi et al. (2016). The innovation platform approach can take a number of CSA technologies to scale as it has been applied in different parts of SSA to scale conservation agriculture, integrated soil fertility management, crop diversification, stress-adapted crop germplasm among others, particularly in Southern Africa (see (Makate and Mango, 2017; Mango et al., 2015, 2017; Nyikahadzoi et al., 2012; Siziba et al., 2013)). The approach has a huge potential of addressing problems of low adoption and impacts of CSA innovations in SSA if given relevant policy and institutional support. The approach overlaps with other suggested approaches e.g. the value chain development and market development approaches in that some of the key stakeholders of the platform (e.g. farmers, marketers, consumers) can also be the key value chain players targeted for value chain upgrading. It greatest advantage lies in its ability to bring all relevant stakeholders within a particular community together in identifying pertinent problems and providing solutions to them. In so doing it motivates every other stakeholder (from an ordinary farmer to high level decision makers in government) in performing their roles and that will bring success.

6.5. Social movements approach

Social movements which are, basically, groupings of diffusely organized people working towards a common societal goal can be crucial to scaling of agricultural technologies. Such groupings are driven by culture and they bank much on learning from each other, sharing wisdom, knowledge and creativity in addition to information and skills (Holt-Giménez, 2001; Rosset et al., 2011; Rosset and Martínez-Torres, 2012). Technology transfer becomes part of a culture and this can be a key factor for successful scaling of proven innovations with this approach. Social movements are widespread and have been successful in scaling up sustainable agricultural practices in South America (Holt-Giménez, 2001; Rosset et al., 2011). An example of such is the *Campesino a Campesino (CaC) Movement* in South America (see (Holt-Giménez, 2001; Rosset et al., 2011; Rosset and Martínez-Torres, 2012)). Motivational forces nurtured through cross visits, farmer meetings, and inclusion of farmer promoter teams are some of the noted but important factors for success in scaling agricultural innovations in South America (Holt-Giménez, 2001). Social movements can also be a platform for taking CSA technologies/practices to scale in SSA. They can offer home grown solutions to the necessary support (e.g. financial and extension) needed for sustaining local interventions on climate change adaptation in smallholder agriculture. Financial support can come through community local savings groups whilst extension support can be through farmer-to farmer learning or through cross-farm visits just to give as examples. Like other participatory approaches (e.g. the innovation platform and cooperatives approach), social movements benefit much from people's culture and social networks. However, in practice, the highlighted participatory approaches are not similar and they do not yield similar outcomes, which justifies why they all need to be considered. As highlighted in the conceptual framework, smallholder farming communities are so much diverse in characteristics and hence choice of participatory approaches to use in upgrading CSA efforts need to be in tandem with context specific attributes of targeted communities. Social rural movements have also been used in pushing for land and agrarian reforms in Africa, Asia and Latin America (Moyo and Yeros, 2005). Their (social movements) greatest strength is that they are well embedded in culture and social networks of the people which can significantly enhance their success.

6.6. Climate smart village approach

The Climate Smart Village (CSV) approach is based on the CSA theory by Lipper et al. (2014) and it is an Agricultural Research for Development (AR4D) approach used to test, through participatory methods, technological and institutional options for climate change adaptation and mitigation in agriculture (Aggarwal et al., 2018). The main aim of the CSV approach is to generate at local scales evidence on what CSA options work best, why, where, how and use such evidence to draw out lessons for scaling the CSA innovations. Precisely, lessons drawn out will provide necessary ammunition for policy makers, agricultural development practitioners, and investors for scaling CSA innovations from local to global levels. Typical steps that will lead to scaling of CSA innovations in a CSA approach include:

Baseline assessment-this involves assessing the initial conditions regarding the exposure, sensitivity and adaptive capacity of communities to climate change (vulnerability assessment), local knowledge base, information, technologies, markets and other services currently available, and other related baseline components.

Design- based on the baseline conditions outcomes, a strategic portfolio of weather, water, seed/breed, carbon/nutrient, and institutional/market smart options are identified and prioritized. The final portfolio developed will aim to achieve high productivity, income, food security, climate resilient farming systems and climate change mitigation where possible.

Creating evidence- prioritized CSA practices and technologies will then be tested through on-farm, on-station trials and surveys among other methods to create evidence of their potential and actual impacts. Due consideration is also given to synergies, trade-offs, and complementarities of the portfolio of technologies chosen. More so, dynamics in adoption are also an important consideration, mainly constraints of adoption.

Scaling up- once CSA innovations and practices have been demonstrated to work, generated evidence is then used to contribute to scaling of the innovations. Horizontal scaling up (adoption) is mainly promoted through farmer-farmer learning, private-sector business models and/or through local government plans, programs, and policies. Vertical

scaling up is attained through improvements in CSA investments, mainstreaming of institutional changes and/or policy changes. Like other participatory approaches, the CSV approach benefits more from farmer social networks and well established, functioning agriculture value chains.

According to Aggarwal et al. (2018), unlike most agricultural development projects which vanish after funding dries up, the CSV approach ensures continuity as it focuses much on building and strengthening capacities of local communities, empowering them and their local organizations which eventually reduces reliance on external support. More on theory and success stories on this approach can be found in Gonsalves et al. (2015); Ojango et al. (2015); Aggarwal et al. (2015), 2018; Brouder and Gomez-Macpherson (2014); and Bayala et al. (2016) amongst other sources. Monitoring, evaluation and learning are continuous processes with the CSV approach.

6.7. Local community based partnerships

Scaling of CSA technologies and practices can also be achieved by community based organizations that are diverse in composition and have partnerships. Community based organizations will have a prime aim of making farmers adapt and be active participants in creating and improving awareness of CSA technologies and practices and also in disseminating information on the technologies and practices on a wider scale. Case studies of scaling up agroforestry in Kenya show a perfect example of such community based organizations (Qureish et al., 2001). Community based organizations; including village, organizations, development partners, village farmer research committees, government ministries, educational institutions such as schools, non-governmental organizations, churches and other social groups were reported to be effective in taking agroforestry practices to scale in Western Kenya. The community based organizations like other participatory approaches discussed, bank on collective decision making, and corporate social responsibility. Communities develop a sense of ownership of the scaling process as they will be actively involved in almost everything to do with the process, including making key decisions. The main benefits of community based approaches has been reported to be the greater cohesion and strengthening of relations between farmers and key local institutions such as government extension, non-governmental organizations, civil society and other key players in information provision plus other necessary institutional support. More so, farmer participation and innovation capacities are also enhanced (Qureish et al., 2001).

7. Success factors for scaling of CSA innovations

From the reviewed literature, a number of factors including policy, and institutional factors, have been found to be critical in ensuring success of scaling efforts. Some of the factors are discussed in this section. Success of CSA scaling interventions include realization of more quality benefits by people from CSA innovations and also ensuring continuity in CSA scaling work (sustainability).

Overall, scaling success of agricultural interventions (ensuring intended outcomes are achieved e.g. food security) is explained by a number of factors in literature, some of which are briefly discussed here. Discussed here are factors that ensure success (both ultimate outcomes and sustainability) of CSA scaling interventions:

i Clear tangible benefits from technologies:
Technologies with clear and tangible benefits for farmers have been found to face less scaling challenges. For instance, several studies have found that, where technologies address immediate farmer problems and concerns such as declining yields, damaging pests and stock feed shortages, farmer uptake and adaptation of the technologies has been greater (Douthwaite et al., 2007; Millar and Connell, 2010; Ojiem et al., 2006; Stur et al., 2002). On the contrary, adaptation and uptake of technologies have been reported to be less where benefits are more diffuse and long term (Kiptot et al., 2007; Mendham et al., 2007; Pannell et al., 2006). In addition, need (brought about by highly degraded agro-ecosystems, high cost and diminishing returns to credit and external inputs) was found to be a key factor for scaling sustainable agriculture and technologies in South America (Holt-Giménez, 2001). With regards to continuity, genuine need for innovations in targeted communities promotes continuity of scaling processes (Millar and Connell, 2010; Pachico and Fujisaka, 2004).

ii Peer learning through the scaling process:
Peer learning, monitoring and evaluation are also key success factors for scaling agricultural technologies/practices (Winowiecki et al., 2015). When farmers are engaged in a facilitated, interactive environment (like with the innovation platforms approach) which allow them to innovate and be able to test technologies within specific environments, compare outcomes with their peers, and see impacts as they emerge, that may influence their initial judgements on that particular technology (Bentley et al., 2007; Pannell et al., 2006). It is therefore important that researchers, extension, development partners and other stakeholders interested in ensuring agriculture technologies are taken to scale develop sound understanding of how farmers learn, innovate and evaluate innovations and how they make decisions within families and social structures (Cary et al., 2002; Pannell et al., 2006; Scoones and Thompson, 1994), as this is key in technology scaling success. More so, monitoring and evaluation should be part of the agriculture technology scaling process as it determines success of the process through creating important knowledge through giving feedback (Ajayi et al., 2018; Hatmann and Linn, 2008). Such feedback then promotes learning for farmers and other stakeholders involved. It therefore, means stakeholder interaction in the action arena should be strictly monitored and evaluated and lessons for improvement must be noted.

iii Support from stakeholders:
Critically important for success of technology-scaling processes is vital support from stakeholders, be it government, civil society, local institutions, non-governmental organizations among other stakeholders (Ajayi et al., 2018). Robust support makes the whole scaling process easier and hence improves rate of success. As highlighted within the conceptual framework and in earlier sections in text, meaningful stakeholder participation is crucial and it enhance success of the scaling process. Technologies adoption is generally constrained by lack of resources (Long et al., 2016). However, with relevant support from various stakeholders, availability of resources will improve and this enhance success of scaling processes.

iv Availability of stimuli and low start-up capital:
Scaling success of innovations is highly likely when the level of start-up capital required for their adoption is low. Innovations which do not require high start-up capital and/or high labour input in the starting phase promote sustainability (IIRR, 2000; Pachico and Fujisaka, 2004). In addition, having something to act as a stimulus to the scaling process for instance, market demand, champion farmers or a critical mass of farmers fuelling the process also promotes success of scaling interventions.

v Access to key resources:
Access to markets, credit, land, information, complementary inputs and a favourable political environment are also important factors for successful CSA scaling. However, absence of such factors cannot completely impede farmers to benefit from suitable technologies and other favourable scaling system changes, especially if their livelihoods impacts are positive and significant (Millar and Connell, 2010). Access to key resources is key and they must be a facilitating structure to ensure that all required resources are available for the scaling activities. Availability of a facilitating structure to aid the scaling up process, making sure that required resources are in place (including agronomic inputs), technical information is available in

printed material and in the appropriate language which is simple and understandable. Well defined structures promote sustainability. Access to the required resources can also help farmers in testing and implementing the new innovations. Ability of farmers to test available innovations (Triability) is an important characteristics of innovations which can help explain their adoption (Rogers, 2003).

Access to resources including credit for the farmer increase his/her economic opportunities (World Bank, 2001). Access to credit is the most important pathway a farmer can access much needed complementary inputs for CSA such as fertilizers, seed among other inputs (Swaminathan-H and et al., 2010). It therefore implies that access to credit can lower scaling challenges and improve adoption of CSA technologies of demonstrated effectiveness in smallholder farming. Access to credit also improves the propensity for farmers to make meaningful CSA investments on the farm e.g. building water reservoirs for irrigation and buying irrigation equipment. As stated by Doss (2006) credit may improve technology adoption on the farm as some technologies require initial capital investments (Bidogeza et al., 2009; Makate et al., 2018).

Access to markets or market linkages improves both access to complementary resources (e.g. seed, fertilizers) and access to income (through market participation). It therefore means that if farmers have access to functional markets scaling success of CSA interventions is enhanced. As discussed under the market driven and value chain development approaches, market development improves demand for productivity improving technologies such as CSA technologies.

Also, access to land or size of land occupied by the farmer has a bearing on technology adoption. Farm size is often one of the first factors measured when modelling adoption processes. Empirical studies have consistently shown farm size to be significantly related to the adoption of new technology (Bidogeza et al., 2009; Ghimire and Huang, 2015; Makate et al., 2018; Mazvimavi and Twomlow, 2009). Various other assets that maybe at the disposal of the farmers have a bearing to their propensity to adopt innovations including CSA innovations. It therefore means disparities in access and possession of various forms of assets can negatively affect CSA scaling. Access to information is also a big driver of technology adoption in smallholder agriculture (Fischer and Qaim, 2012) and can also enhance scaling success of CSA innovations.

vi Considering farmer socioeconomic diversity:

Additional factors that can influence success of scaling initiatives include diversity in people's culture, and their socioeconomic conditions (farmer and community attributes as discussed under the IAD framework). Due consideration of diverse farmer cultures and other socioeconomic conditions can increase success rate of CSA scaling practices and processes. More so, quality of commitment and participation from the community people and partners, and supporting government resources and policies can also determine success of technology scaling projects/initiatives (Gillespie, 2004; Gundel et al., 2001; Kolavalli and Kerr, 2002; Millar and Connell, 2010; World Bank et al., 2003).

Formulation of equitable culture-inclusive CSA policies formulated using participatory approaches, ensuring interventions are gender inclusive and also noting critical factors resulting to gender inequality in access to key farming resources and other aspects within communities, are some of the factors if given due consideration throughout the scaling process that can ensure scaling success (Westermann et al., 2018, 2015). In addition, ensuring equitable access to key resources (land, labour, capital, information) and access to markets and other key institutions can also minimise scaling challenges as previously discussed. Considering farmer heterogeneity both in terms or resource access and personal characteristics is therefore very important in order to enhance success of development interventions (Barrett et al., 2005; Ruben and Pender, 2004) including CSA innovations scaling success. This is mainly because, farmers will devise farming systems and or livelihood strategies that provide the best guarantee for survival based on their socioeconomic conditions/ vulnerability (Barrett et al., 2005; Makate and Mango, 2017; Ruben and Pender, 2004). This highlight why initial conditions (farmer characteristics, resource endowments, cultures, community attributes, local legal frameworks and many other factors) must be given due consideration in CSA scaling work. Failure to devise strategies in tandem with such factors in any given community can fail CSA scaling efforts.

8. Policy and institutional focal areas important for scaling

8.1. Policy defined

A policy can be defined as a plan or course of action, as of a political party, business, or government, envisioned to influence and determine actions, decisions, and other matters (Saigal, 1983; Dye, 1992; Rose, 1993). In another sense, policies can be understood as general statements or understandings which are used to guide or channel course of action or thinking in decision making (Dye, 1992; Dror, 2017). As put in definitions by Nakamura (1987) and Dror (2017), a policy is a purposive course of action taken to deal with a concern or problem (Nakamura, 1987; Dror, 2017). Friedrich (1940) defines policy as a planned course of action of an individual person, group or of people or government within a given environment, providing opportunities and obstacles which the policy was proposed to utilize and overcome with the ultimate effort of reaching a particular goal or attaining an objective. From the aforementioned definitions, it is evident that a policy or policies have a purpose, set goals (what is to be achieved), proposals or plans (means of achieving set goals), programs (means of pursuing goals), decisions or choices (actions taken in setting goals, developing plans, implementation, monitoring and evaluation of programs etc.), and outcomes (effects on society either positive or negative) (Saigal, 1983; Cairney, 2011; Dror, 2017; Vedung, 2017). Policy strategies in this paper therefore means various courses of actions and considerations that can be taken to overcome CSA scaling challenges with the ultimate aim of improving CSA scaling success. Some of the policy strategies may include the set laws, treaties, administrative actions, statements, regulations and funding priorities from top decision makers in government, regional bodies among other concerned parties in support of CSA scaling actions.

8.2. Institutions defined

Institutions are humanly created formal and informal mechanisms that shape social and individual expectations, behaviour and interactions (Agrawal, 2010; North, 1990; Ostrom, 1990). Informal institutions are a set of informal rules that exist outside and alongside structures of government whilst formal institutions are the laws and public policies written and documented (Raymond and Weldon, 2013). Both formal and informal institutions influence human behaviour and are therefore important in scaling of CSA interventions. Some of the institutions that can be highly important in CSA scaling interventions include public, private and civic institutions (Agrawal, 2010). Private institutions can include Non-Governmental Organizations (NGOs), charitable organizations, private businesses (e.g. agro-dealers in seed, fertilizer, agrochemicals, insurance, loan dealers). Public institutions include government institutions (extension, financial, research institutions etc.) while civic society institutions include farmer organizations, cooperatives, savings and loan groups, churches and other civil society groups. Institutional strategies and focal areas will therefore include the patterns of organizational actions and priorities that are directed at leveraging and shaping the institutions in CSA scaling activities (Lawrence, 1999).

8.3. Policy and institutional focal areas

A hybrid of policy and institutional actions is required to facilitate scaling of CSA interventions of demonstrated effectiveness. More so, policy and institutional strategies/actions must be locally context specific in order to ensure success and sustainability of scaling processes. From the scaling approaches and scaling success factors highlighted earlier, it is evident that, policy and institutional actions should focus on: (i) making key inputs available at affordable prices (e.g. fertilizer, chemicals, seed, equipment, among others), (ii) ensuring that markets are functional and that they promote beneficial trade, (iii) ensuring availability of credit (finance), (iv) ensuring secure access to land, (v) ensuring access to efficient extension services and information, (vi) infrastructure development, and (vii) governance, should be part of the CSA scaling policy package. Generally, the government or regional policy making body should make sure that conditions in all the aforementioned factors should be favourable in order to increase chances of success in CSA scaling.

Literature even points to the importance of a regulatory and policy support framework for the success of technology scaling projects in agriculture (Ajayi et al., 2018; Hatmann and Linn, 2008; USAID, 2014). Policies that can act as dis-incentives to scaling of technologies such as pervasive subsidies (directed only to a selected few market actors), stringent and burdensome regulatory requirements especially in agri-food chains (Lee and Gereffi, 2015; Lee et al., 2012), price regulations, ill-defined land tenure security, monopolies in output processing and trading among others should be avoided. More so, lack of equality in treating farmers, no deliberate targeting of vulnerable groups (the poor farmers, women and youth farmers) can act as disincentives in scaling technologies and their impacts to the wider society. Hatmann and Linn (2008) reiterated that, policy and legal frameworks must be adopted to support technology scaling up activities if the scaling process is to succeed. Furthermore, USAID (2014) echoed that, scaling of productive technologies can be severely constrained by the policy environment.

Also, policy and institutions should clearly define intellectual property rights for effective scaling efforts. By definition, intellectual property rights are awards to investors and institutions of certain exclusive rights to produce, copy, distribute, and license goods and technologies (World Bank, 2005). Intellectual property rights give innovators personal property ownership rights and a means to prevent unauthorized use of their work (USAID, 2014). Clearly defined entitlement to land ownership for instance, can influence level of investment in CSA technologies by smallholder farmers (Barrows and Roth, 1990; Lawry et al., 2017). In principle, property rights systems must balance public interest in accessible, affordable, livelihood enhancing technologies with reality that some market power may stimulate innovation by facilitating recovery of related expenses and financial risk management (Ajayi et al., 2018). It therefore implies that policy and institutional actions should clearly define property rights for effecting scaling of CSA technologies in African smallholder farming areas.

In addition to aforementioned focal areas for policy and institutions literature also point to the importance of policy and institutions prioritizing some key areas in CSA scaling work such as: dealing with market constraints, gaining advocacy and political will, prioritizing capacity development, ensuring accountability in CSA scaling projects, strict monitoring and evaluation, ensuring flexibility of institutions (e.g. in resources availability), financial support, and embracing local institutions. The factors are briefly discussed here as follows:

i Dealing with market constraints:
Reducing potential market constraints is a key area to focus on to ensure market incentives remain intact for producers. Policy and institutional actions to minimise negative price effects through regulation can improve scaling success. Market development including access and viability is essential for scaling up of agricultural technologies (IIRR, 2000). Improving access to market information, improving market linkages and availing improved market infrastructure amongst other development can be important strategies of improving adoption of CSA technologies by farmers. Generally, lowering market constraints reduces transaction costs for farmers and this improves access to CSA technologies (e.g. stress-tolerant seed varieties) and also improves access to output markets for their produce. Institutions, both formal and informal should therefore prioritize reducing market constraints for farmers in order to improve CSA scaling success. In other words, policy and institutions should promote market development.

ii Advocacy and political will:
Gaining political will and support is important for the scaling of CSA technologies. As strategies, institutions in CSA scaling can perform some political outreach programs, lobbying to influence policy makers, mobilising and networking via both professional and political channels, and educating civil servants can help in advocacy (Ajayi et al., 2018). Political support is essential in expanding and sustaining CSA scaling projects (FAO, 2009; Kohl, 2007). However, the focus should be on building coalitions of political stakeholder support and commitment as political parties come and go whilst scaling up initiatives/projects are long-term processes (Ajayi et al., 2018). If not carefully managed, political advocacy can bring risks to the scaling process. In literature, some scaling projects failed to get political support by current leaders because scaling initiatives were initiated by political rivals (Roothaert and Kaaria, 2004). Stakeholder institutions involved in CSA scaling should therefore establish useful alliances with political decision makers at the same time minimizing potential adverse risks.

iii Capacity building:
Building capacities of institutions including their personnel is also a key aspect in CSA scaling projects. Quality training of personnel and good incentives are recommended. Training and re-training of existing personnel is essential in CSA scaling as climate change itself presents a new challenge which needs new or improved expertise. Literature including Binswanger and Nguyen (2005); USAID (2014); Long et al. (2016) just to give a few examples, have recommended capacity building as a key step in scaling technologies and practices in agriculture. For instance, revitalised extension services for CSA will need retraining of extension workers and improving institutional capacities (in terms of resources) to rightfully deal with the new challenge (climate change) without compromising their capacities to deal with conventional challenges. For instance, building capacity of a ministry (e.g. ministry of agriculture, environment or forestry) in dealing with CSA issues can be in the form of establishing a CSA unit within that ministry e.g. agriculture. Such an action will improve the capacity of the ministry in dealing with CSA issues and scaling which can yield sustainable outcomes in scaling efforts. Both formal and informal institutions should therefore prioritize capacity building of their institutions and that of the people they serve if they are to improve CSA scaling success.

iv Accountability:
Accountability is a key element in project management. Accountability can be defined as the means by which individuals or institutions report to a recognized authority (or authorities) and are held responsible for their actions (Edwards and Hulme, 1996). Similarly, Fox and Brown (1998) defined accountability as the process of holding actors responsible for their actions (Ebrahim, 2003). Stakeholder institutions in CSA scaling should ensure accountability to enhance chances of scaling success. Some of the tools institutions can use to ensure accountability include: adopting performance assessment and evaluation, adopting participatory approaches in management, self-regulation, social auditing, and using disclosure statements and reports as expansively discussed in Ebrahim (2003). Accountability at institutional level is essential for

ensuring that resources are aligned to organizational objectives. Embezzlement of CSA scaling project funds and issues related to corruption can constrain effective scaling of CSA projects. Accountability will ensure that goals of institutions and that of the broader society are all met in scaling up processes. Accountability has been reported as key to the success of projects (see for example Sohail and Cavill (2008) and Bruzelius et al. (1998)).

v Monitoring and evaluation:
As highlighted earlier in text, successful scaling of agricultural technologies requires regular feedback from monitoring and evaluation systems (Ajayi et al., 2018; IFAD, 2010; Kohl, 2007; Millar and Connell, 2010; USAID, 2014). This is critical as it allows for corrective measures or any necessary adjustments to be made in implementation of scaling programs. Monitoring and evaluation will not only give important feedback on unforeseen aspects, but can also educate on the opportunities and constraints for further scaling in projects/programs (IFAD, 2010). More so, monitoring and evaluation will promote peer learning, which is an important driver for further scaling (especially adoption). Related, monitoring and evaluation will bring out clearly, what works and doesn't work, which promotes learning and reflection amongst stakeholders in scaling. Through continuous monitoring and evaluation, institutions can create greater awareness on scaling up aspects. Overall, effecting monitoring and evaluation can improve effectiveness and efficiency in scaling of CSA innovations. Literature has also hailed monitoring and evaluation for improving efficiency and effectiveness of interventions (Casley and Lury, 1982; Crawford and Bryce, 2003). Institutional actions and policy frameworks should ensure CSA scaling interventions are well monitored and evaluated.

vi Flexibility:
Policy frameworks adopted in scaling up processes will need to be flexible and be able to accept, adapt and internalize change. That said, institutions lacking capacity to operate larger programmes are said to be at higher risk of facing serious scaling obstacles (Ajayi et al., 2018). Unwillingness to change to meet requirements for scaling up, and lack of skills, systems and manpower to manage the increased program are two major problems involved. However, for successful scaling, institutions must be flexible in order to accept and adapt to change or even seek appropriate partnership for them to be effective in scaling up activities. Flexibility of institutions require access to the necessary and/or required resources e.g. competent labour force, adequate financial resources, technology just to mention a few. Institutions must therefore prioritize actions that improve their flexibility in CSA scaling work.

vii Financial support:
Also, vertical scaling up which often involves expanding scope of scaling projects at institutional level obviously demand more financial resources. As such, financial support or adequate finance is a critical strategy for institutions to sustain scaling processes. Financial resources need to be mobilised to support scaled up interventions while costs of interventions need to be adapted to fit into available financial space (Ajayi et al., 2018; IIRR, 2000). More importantly, financial sustainability is critically needed to ensure continuity and hence greater impact to society from scaling up projects. Institutions should ensure adequate resources are obtained and possibly source financial support at local levels (i.e. from government) to ensure sustainability of scaling up processes. As highlighted earlier, gathering adequate financial resources will not only ensure sustainability of CSA scaling processes but will also promote flexibility.

viii Embracing local institutions and indigenous technical knowledge:
More importantly, scaling of CSA technologies of demonstrated effectiveness in smallholder farming need to find effective means of fully embracing indigenous knowledge systems and giving local institutions central roles in scaling work. Local formal and informal institutions need to be given a central role and responsibilities in designing, planning and implementing policies, projects and programs meant to scale adoption of the innovations (Agrawal, 2010; Meinzen-Dick et al., 2013). Embracing local institutions can bring positive results in improving scaling success through improving information gathering and dissemination, skills development and capacity building, resource mobilization, creating networks, providing leadership among other key functions (Agrawal, 2010; Raymond and Weldon, 2013) which are key elements for awareness and subsequent adoption of proven CSA technologies. Further, local institutions are also important as they can promote innovation in local communities. However, for this to happen, and as previously discussed, there will be need for investment in capacity development. It is therefore, important that external players understand which local institutions are present in the communities they will be targeting, including their interests, capacities, connections, challenges and strengths before offering external support. With this, they can increase chances of success for their interventions, by complementing activities of local institutions already working in such communities.

More so, fully embracing indigenous knowledge systems embedded in targeted communities will also promote effective participatory approaches in promoting adoption of CSA technologies in rural communities which raises chances of success. According to Nyong et al. (2007), sustainability of agricultural projects in local areas are highly sustainable if local people are seen as partners in the project with joint ownership. The noble thing to do to get the best out of indigenous knowledge systems in spreading CSA technologies will be recognizing its existence and then incorporating it into designs, plans, and implementation frameworks for promoting the technologies. Adopting bottom-up approaches can be the best way of embracing indigenous knowledge. If development partners adopt a bottom-up approach in promoting adoption of CSA technologies for improved climate resilience in agriculture, it will ensure high level of participation among local communities which enhances chances of success. Important to note is however, that formal scientific knowledge systems should complement rather than replace indigenous knowledge systems. This is reasonable since research has found that a hybrid of external institutions and indigenous practices enhance adaptive capacity and resilience of local communities to climate change (see Upton (2012) for an example in pastoral communities).

9. Conclusions and recommendations

This research has identified possible approaches, success and sustainability factors, policy and institutional strategy focal areas that can enhance scaling success of CSA technologies and practices of demonstrated effectiveness in smallholder farming. Through the identification of possible approaches for taking CSA technologies and practices to scale, plus policy and institutional strategy focal areas important in scaling CSA innovations, the study contributes to scarce and emerging literature on scaling CSA novel technologies and practices in smallholder farming. This is very important since low uptake of CSA innovations remain a reality in developing regions particularly in SSA despite demonstrated effectiveness of various CSA technologies and practices.

By undertaking this study, a number of possible approaches that can be adopted in scaling up or scaling out CSA innovations and their impacts were identified. Approaches are mostly participatory and they span from smallholder value chain upgrading and development, innovation platform approach, social movements, climate smart village approach, cooperatives, to market driven approaches. Adopting a mix of approaches in ways that exploit potential useful synergies while minimising adverse trade-offs can yield improved outcomes. This approach is more likely to work better, given that farmers are often found to adopt more than one CSA technology or practice at a time and the

technologies/practices themselves are not accessed through similar channels. For instance, adoption of drought tolerant crop varieties can be easily promoted through improving formal and informal market access (value chain development) which may not be exactly the same with improved market information services or promoting soil, land and water conservation technologies. Social movements or cooperatives may perform better in the case of upgrading soil, land and water conservation practices as noted in reviewed literature. Since farmers may need a hybrid of synergistic technologies at a time, the research and development community needs also to combine approaches in upgrading CSA interventions. Similar observations have been noted in related literature (see Ajayi et al. (2018). Also, as highlighted under the IAD framework, diversity in farmer attributes, their local contexts and other community attributes calls for integrated approaches in suggesting strategies for scaling/upgrading interventions. A basket of synergistic strategies can therefore improve chances of scaling success in diverse heterogeneous communities.

In addition, several policy and institutional strategy focal areas that can improve scaling success of CSA interventions are identified including embracing local knowledge systems, dealing with market failure, ensuring availability of agricultural support services for farmers (in credit land tenure, inputs, infrastructure etc.), gaining advocacy and political will, capacity building local institutions and their personnel, ensuring flexibility and accountability by institutions, and devising sustainable financing mechanism for CSA activities. Generally, a hybrid of conducive and complementary policy and institutional actions are required to enhance scaling success. For instance, availability of CSA technologies through the market (e.g. improved varieties and insurance) may need complementary efforts towards mechanization of agriculture, improving access to agricultural advisory services, and improving access to complementary inputs, and finance, among other key factors.

In conclusion, scaling of CSA innovations cannot just happen by itself, there is need for facilitation in terms of conducive policy and institutional actions. Policy and institutions can play a very important role in aiding scaling of CSA innovations. Policy and institutional strategies are important as they clearly define the rules of the game that will ultimately establish responsibilities in the scaling process by stakeholders. With a clearly defined and established policy framework, stakeholders can clearly tell who does what, when and on what condition. Policy should create a conducive environment for CSA scaling activities. This can be achieved by ensuring that policy frameworks adopted promote equitable access to inputs, trade and market opportunities, credit, land and tenure security, good infrastructure, good governance among other important elements. Additionally, institutional strategies relating to dealing decisively with marketing constraints, gaining political will and support for CSA scaling activities, capacity building (institutions, their employees, farmers and other stakeholders), promoting accountability in CSA project activities, establishing effective monitoring and evaluation frameworks, flexibility of institutions, financial stability, complementing formal knowledge systems and institutions with scientific knowledge systems are critical for ensuring successful scaling of CSA activities and their impacts. Institutions involved (either private, civic or public institutions) should prioritize making aforementioned focal areas conducive for CSA scaling if successful outcomes are to be achieved.

Finally, a well-defined policy and institutional framework will not only help farmers in successfully adopting CSA innovations, but it will also help supporting organizations and other stakeholders to demonstrate the much needed willingness in facilitating the scaling processes in the long-term. More so, a conducive policy and institutional framework and actions can minimize farmer challenges, reduce CSA adoption constraints, and enhance sustainability in scaling processes which can ultimately improve impacts of CSA innovations to society. Positive significant impacts of successful CSA scaling will have a positive feedback effect on both initial conditions (i.e. improving farmer conditions and community attributes) and CSA action environment.

Acknowledgements

The author is grateful to earlier comments and suggestions from anonymous reviewers and the Editor/s of this journal that have improved the quality of the manuscript. This work was supported by the Africa Centre of Excellence for Climate Smart Agriculture and Biodiversity Conservation.

Appendix A. Summary of literature source types used in writing the review

Item	Literature source type	Number	Details
1.	Journal articles	79	This cover only Peer reviewed journal articles used in review
2.	Books/book chapters	17	Books and book chapters used in writing the review
3.	Reports	16	Reports from various organisations used in writing the review e.g. reports from FAO, IFAD, FARA, World Bank, IPCC, IFPRI, IIRR, WAGENINGEN UR etc.
4.	Online sources/ PowerPoint presentations	6	Presentations and online sources used in writing the review
5.	Conference papers	4	Conference proceedings
6.	Concept /occasional papers/working papers/ discussion papers	12	Discussion, occasional, working and discussion papers used
7.	Databases	1	Harvard Dataverse (e.g. CGSPACE cgspace.cgiar.org)
	Total	135	Total number of sources

Notes: IFAD = international Fund for Agricultural Development; FAO = Food and Agricultural Organization; FARA = Forum for Agricultural Research in Africa; IPCC = Intergovernmental Panel on Climate Change; IFPRI = International Food Policy Research Institute; IIRR = International Institute of Rural Reconstruction.

References

Abebaw, D., Haile, M.G., 2013. The impact of cooperatives on agricultural technology adoption: empirical evidence from Ethiopia. Food Policy 38, 82–91.
Adekunle, A., Fatunbi, A., 2012. Approaches for setting-up multi-stakeholder platforms for agricultural research and development. World Appl. Sci. J. 16, 981–988.
Adekunle, A., Hawkins, R., Heemskerk, W., Booth, R., Daane, J., Maatman, A., Nederlof, S., Defoer, T., Sellamna, N., Gildemacher, P., 2009. Integrated Agricultural Research for Development (IAR4D). Forum for Agricultural Research in Africa (FARA).
Adekunle, A., Fatunbi, A., Jones, M., 2016. How to Set up an Innovation Platform. A Concept Guide for the Sub-Saharan Africa Challenge Program (SSA CP). Accra. Forum for Agricultural Research in Africa, Ghana.
Aggarwal, P.K., Singh, A.K., Samra, J.S., Singh, G., Gogoi, A.K., Rao, G.G.S.N., Ramakrishna, Y.S.I., 2009. Introduction. In: Aggarwal, P.K.E. (Ed.), Global Climate Change and Indian Agriculture. Indian Council of Agricultural Research, New Delhi, India.
Aggarwal, P., Zougmoré, R., Kinyangi, J., 2015. Climate-Smart Villages: a Community

Approach to Sustainable Agricultural Development. CGIAR Research Program on Climate Change. Agriculture and Food Security (CCAFS), Copenhagen, Denmark.
Aggarwal, P.K., Jarvis, A., Campbell, B.M., Zougmoré, R.B., Khatri-Chhetri, A., Vermeulen, S.J., Loboguerrero, A., Sebastian, L.S., Kinyangi, J., Bonilla-Findji, O., Radeny, M., Recha, J., Martinez-Baron, D., Ramirez-Villegas, J., Huyer, S., Thornton, P., Wollenberg, E., Hansen, J., Alvarez-Toro, P., Aguilar-Ariza, A., Arango-Londoño, D., Patiño-Bravo, V., Rivera, O., Ouedraogo, M., Tan Yen, B., 2018. The climate-smart village approach: framework of an integrative strategy for scaling up adaptation options in agriculture. Ecol. Soc. 23, 14.
Agrawal, A., 2010. Local institutions and adaptation to climate change. In: Mearns, R., Norton, A. (Eds.), Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World. The World Bank, Washington DC, pp. 173–178.
Ajayi, M.T., Fatunbi, A.O., Akinbamijo, O.O., 2018. Strategies for Scaling Agricultural Technologies in Africa. Forum for Agricultural Research in Africa (FARA), Accra Ghana.
Arslan, A., McCarthy, N., Lipper, L., Asfaw, S., Cattaneo, A., 2014. Adoption and intensity of adoption of conservation farming practices in Zambia. Agric. Ecosyst. Environ. 187, 72–86.
World Bank, 2005. Intellectual Property and Development, Lessons from Recent Economic Research. World Bank and Oxford University Press, Washington DC.
Barrett, C.B., Swallow, B.M., 2006. Fractal poverty traps. World Dev. 34, 1–15.
Barrett, C.B., Clark, M.B., Clay, D.C., Reardon, T., 2005. Heterogeneous constraints, incentives and income diversification strategies in rural Africa. Q. J. Int. Agric. 44, 37–60.
Barrows, R., Roth, M., 1990. Land tenure and investment in African agriculture: theory and evidence. J. Modern Afr. Stud. 28, 265–297.
Bayala, J., Zougmoré, R., Ky-Dembele, C., Bationo, B.A., Buah, S., Sanogo, D., Somda, J., Tougiani, A., Traoré, K., Kalinganire, A., 2016. Towards developing Scalable Climate-Smart Village Models: Approach and Lessons Learnt from Pilot Research in West Africa. ICRAF Occasional Paper. .
Bentley, J., Velasco, C., Rodriguez, F., Oros, R., Botello, R., Webb, M., Devaux, A., Thiele, G., 2007. Unspoken demands for farm technology. Int. J. Agric. Sustain. 5, 70–84.
Bidogeza, J., Berentsen, P., De Graaff, J., Lansink, A.O., 2009. A typology of farm households for the Umutara Province in Rwanda. Food Security 1, 321–335.
Binswanger, H., Nguyen, T.-V., 2005. A step by step guide to scale up community driven development, African water laws: plural legislative frameworks for rural water management in Africa. Proceedings of a Workshop Held in Johannesburg 26–28 January 2005.
Bostedt, G., Hörnell, A., Nyberg, G., 2016. Agroforestry extension and dietary diversity–an analysis of the importance of fruit and vegetable consumption in West Pokot, Kenya. Food Security 8, 271–284.
Brida, A.B., Owiyo, T., 2013. Loss and damage from the double blow of flood and drought in Mozambique. Int. J. Glob. Warming 5, 514–531.
Brouder, S.M., Gomez-Macpherson, H., 2014. The impact of conservation agriculture on smallholder agricultural yields: a scoping review of the evidence. Agric. Ecosyst. Environ. 187, 11–32.
Bruzelius, N., Flyvbjerg, B., Rothengatter, W., 1998. Big decisions, big risks: improving accountability in mega projects. Int. Rev. Administrative Sci. 64, 423–440.
Campbell, B.M., Thornton, P., Zougmoré, R., van Asten, P., Lipper, P., 2014. Sustainable intensification: what is its role in climate smart agriculture? Curr. Opin. Environ. Sustain. 8, 39–43.
Carter, M.R., Barrett, C.B., 2006. The economics of poverty traps and persistent poverty: an asset-based approach. J. Dev. Stud. 42, 178–199.
Carter, M.R., Little, P.D., Mogues, T., Negatu, W., 2007. Poverty traps and natural disasters in Ethiopia and Honduras. World Dev. 35, 835–856.
Cary, J., Webb, T., Barr, N., 2002. Understanding Landholders'Capacity to Change to Sustainable Practices: Insights About Practice Adoption and Social Capacity for Change. Bureau of Rural Sciences., Canberra.
Casley, D.J., Lury, D.A., 1982. Monitoring and Evaluation of Agriculture and Rural Development Projects. World Bank, Washington DC.
Centner, T.J., 1988. The role of cooperatives in agriculture: historic remnant or viable melllbership organization? J. Agric. Coop. 479.
Crawford, P., Bryce, P., 2003. Project monitoring and evaluation: a method for enhancing the efficiency and effectiveness of aid project implementation. Int. J. Project Manage. 21, 363–373.
Doss, C.R., 2006. Analyzing technology adoption using microstudies: limitations, challenges, and opportunities for improvement. Agric. Econ. 34, 207–219.
Douthwaite, B., Schulz, S., Olanrewaju, A.S., Ellis-Jones, J., 2007. Impact pathway evaluation of an integrated Striga hermonthica control project in Northern Nigeria. Agric. Syst. 92, 201–222.
Ebrahim, A., 2003. Accountability in practice: mechanisms for NGOs. World Dev. 31, 813–829.
Edwards, N., 2010. Scaling-up health innovations and interventions in public health: a brief review of the current state-of-the-science. Inaugural Conference to Advance the State of the Science and Practice on Scale-up and Spread of Effective Health Programs. pp. 6–8.
Edwards, M., Hulme, D., 1996. Too close for comfort? The impact of official aid on nongovernmental organizations. World Dev. 24, 961–973.
FAO, 2009. Scaling up Conservation Agriculture in Africa. Strategy and Approaches. FAO, Rome.
FAO, 2010. Climate-Smart" Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation, Hague Conference on Agriculture, Food Security and Climate Change. Food and Agriculture Organization, Hague, Netherlands.
FAO, 2013. Sourcebook on Climate Smart Agriculture, Forestry and Fisheries. Food and Agriculture Organization of the United Nations (FAO). Food and Agriculture Organization, Rome, Italy.
FAO, 2018. Climate Smart Agriculture: Building Resilience to Climate Change. Springer.
Fatunbi, A.O.A., Youdeowei, A., Ohiomoba, S.I., Adekunle, A.A., Akinbanijo, O.O., 2016. Agricultural innovation platforms: framework for improving sustainable livelihoods in Africa Forum for Agricultural Research in Africa (FARA). Accra Ghana. .
Fischer, E., Qaim, M., 2012. Linking smallholders to markets: determinants and impacts of farmer collective action in Kenya. World Dev. 40, 1255–1268.
Fox, J., Brown, L.D., 1998. The Struggle for Accountability. The World Bank, NGOs, and grassroots movements, Cambridge/London.
Francesconi, G.N., Heerink, N., 2011. Ethiopian agricultural cooperatives in an era of global commodity exchange: does organisational form matter? J. Afr. Econ. 20, 153–177.
Gaiha, R., Thapa, G., 2006. Natural Disasters, Vulnerability and Mortalities – A Cross-Country Analysis. International Fund for Agricultural Development, Rome, Italy.
Ghimire, R., Huang, W.-C., 2015. Household wealth and adoption of improved maize varieties in Nepal: a double-hurdle approach. Food Security 7, 1321–1335.
Gillespie, S., 2004. Scaling up Community-Driven Development: A Synthesis of Experience. International Food Policy Research Institute, Food Consumption and Nutrition Division, FCND Discussion Papers.
Gonsalves, J., Sebastian, L., Joven, B., Amutan, C., Lucerna, A., 2015. Climate-Smart Villages: Key Concepts; Hanoi, Vietnam. CGIAR Research Program on Climate Change. Agriculture and Food Security (CCAFS), Copenhagen, Denmark.
Gundel, S., Hancock, J., Anderson, S., 2001. Scaling-up Strategies for Research Innatural Resources Management: A Comparative Review. Natural Resources Institute, Chatham, UK, pp. 1–61.
Hansen, J., Hellin, J., Rosenstock, T., Fisher, E., Cairns, J., Stirling, C., Lamanna, C., van Etten, J., Rose, A., Campbell, B., 2018. Climate risk management and rural poverty reduction. Agric. Syst In Press.
Hatmann, A., Linn, J.F., 2008. Scaling up: A Framework and Lessons for Development Effectiveness from Literature and Practice, Working Paper 5. Wolfensolin Centre for Development.
Holt-Giménez, E., 2001. Scaling-up Sustainable Agriculture. Lessons from the Campesino a Campesino Movement. LEISA News October. pp. 27–29.
IFAD, 2010. Guidelines for Scaling up. IFAD.
IIRR, 2000. Going to Scale: Can We Bring More Benefits to More People More Quickly?, Conference Highlights. International Institute of Rural Reconstruction (IIRR), Philippines: International Institute of Rural Reconstruction (IIRR).
IPCC, 2007. Climate change 2007: synthesis report. In: Core Writing Team, P., R.K, Resinger, A. (Eds.), Contribution of Working Groups I, II, and III to the 4th Assessment Report. Intergovernmental Panel on Climate Change, New York.
IPCC, 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group 2 to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, New York.
Ito, J., Bao, Z., Su, Q., 2012. Distributional effects of agricultural cooperatives in China: exclusion of smallholders and potential gains on participation. Food Policy 37, 700–709.
Jonasova, M., Cooke, S., 2012. Thinking Systematically About Scaling up World Bank Supported Agriculture and Rural Development Operations: The Case of Competitive Grant Schemes for Agricultural Research and Extension. World Bank Discussion Paper. The World Bank, Washington, DC, USA.
Kiboi, M.N., Ngetich, K.F., Diels, J., Mucheru-Muna, M., Mugwe, J., Mugendi, D.N., 2017. Minimum tillage, tied ridging and mulching for better maize yield and yield stability in the Central highlands of Kenya. 157–166. Soil Till. Res. 170, 157–166.
Kiptot, E., Hebinck, P., Franzel, S., Richards, P., 2007. Adopters, testers or pseudo-adopters? Dynamics of the use of improved tree fallows by farmers in western Kenya. Agric. Syst. 94, 509–519.
Kohl, R., 2007. Key Points for Scaling up, Management Systems International. Power Point Presentation to the Wolfensohn Center.
Kolavalli, S., Kerr, J., 2002. Scaling up participatory watershed development in India. Dev. Change 33, 213–235.
Lawrence, T.B., 1999. Institutional strategy. J. Manage. 25, 161–187.
Lawry, S., Samii, C., Hall, R., Leopold, A., Hornby, D., Mtero, F., 2017. The impact of land property rights interventions on investment and agricultural productivity in developing countries: a systematic review. J. Dev. Effectiveness 9, 61–81.
Lee, J., Gereffi, G., 2015. Global value chains, rising power firms and economic and social upgrading. Critical Perspect. Int. Bus. 11, 319–339.
Lee, J., Gereffi, G., Beauvais, J., 2012. Global value chains and agrifood standards: challenges and possibilities for smallholders in developing countries. Proc. Natl. Acad. Sci. 109, 12326–12331.
Lipper, L., Thornton, P., Campbell, B.M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K., Hottle, R., Jackson, L., Jarvis, A., Kossam, F., Mann, W., McCarthy, N., Meybeck, A., Neufeldt, H., Remington, T., Sen, P.T., Sessa, R., Shula, R., Tibu, A., Torquebiau, E.F., 2014. Climate-smart agriculture for food security. Nature Clim. Change 4, 1068–1072.
Lobell, D., Sibley, A., Ortiz-Monasterio, J.I., 2012. Extreme heat effects on wheat senescence in India. Nature Clim. Change 2, 186–189.
Long, T.B., Blok, V., Coninx, I., 2016. Barriers to the adoption and diffusion of technological innovations for climate-smart agriculture in Europe: evidence from the Netherlands, France, Switzerland and Italy. J. Clean. Prod. 112, 9–21.
Lunduka, R.W., Mateva, K.I., Magorokosho, C., Manjeru, P., 2017. Impact of Adoption of Drought-Tolerant Maize Varieties on Total Maize Production in South Eastern Zimbabwe Climate and Development. pp. 1–12.
Makate, C., Mango, N., 2017. Diversity amongst farm households and achievements from multi-stakeholder innovation platform approach: lessons from Balaka Malawi. Agric. Food Security 6, 37.
Makate, C., Wang, R., Makate, M., Mango, N., 2016. Crop diversification and livelihoods

of smallholder farmers in Zimbabwe: adaptive management for environmental change. SpringerPlus 5, 1–18.
Makate, C., Makate, M., Mango, N., 2017a. Sustainable agriculture practices and livelihoods in pro-poor smallholder farming systems in southern Africa. Afr. J. Sci. Technol. Innov. Dev. 9, 269–279.
Makate, C., Wang, R., Makate, M., Mango, N., 2017b. Impact of drought tolerant maize adoption on maize productivity, sales and consumption in rural Zimbabwe. Agrekon 56, 67–81.
Makate, C., Makate, M., Mango, N., 2018. Farm types and adoption of proven innovative practices in smallholder bean farming in Angonia district of Mozambique. Int. J. Soc. Econ. 45, 140–157.
Mango, N., Nyikahadzoi, K., Makate, C., Dunjana, N., Siziba, S., 2015. The impact of integrated agricultural research for development on food security among smallholder farmers of southern Africa. Agrekon 54, 107–125.
Mango, N., Siziba, S., Makate, C., 2017. The impact of adoption of conservation agriculture on smallholder farmers' food security in semi-arid zones of southern Africa. Agric. Food Security 6, 32.
Masuka, B., Atlin, G.N., Olsen, M., Magorokosho, C., Labuschagne, M., Crossa, J., Bänziger, M., Pixley, K., Vivek, B., van Biljon, A., Macrobert, J., Alvarado, G., Prasanna, B.M., Makumbi, D., Tarekegne, T., Das, B., Zaman-Allah, M., Cairns, J.E., 2017. Gains in maize genetic improvement in Eastern and Southern Africa (i) CIMMYT hybrid breeding pipeline. Crop Sci. 57, 168–179.
Matsuda, M., 2013. Upland farming systems coping with uncertain rainfall in the central dry zone of Myanmar: how stable is indigenous multiple cropping under semi-arid conditions? Human Ecol. 41, 927–936.
Mazvimavi, K., Twomlow, S., 2009. Socioeconomic and institutional factors influencing adoption of conservation farming by vulnerable households in Zimbabwe. Agric. Syst. 101, 20–29.
McCarthy, N., Brubaker, J.R., FAO, 2014. Climate-Smart Agriculture and Resource Tenure in Sub-Saharan Africa: A Conceptual Framework. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.
Megersa, B., Markemann, A., Angassa, A., Zárate, A.V., 2014. The role of livestock diversification in ensuring household food security under a changing climate in Borana, Ethiopia. Food Security 6, 15–28.
Meinzen-Dick, R., Bernier, Q., Haglund, E., 2013. The Six 'ins' of Climate-Smart Agriculture: Inclusive Institutions for Information, Innovation, Investment and Insurance, CAPRi Working Paper No. 114. International Food Policy Research Institute (IFPRI), Washington, DC, pp. 804–816.
Mendham, E., Millar, J., Curtis, A., 2007. Landholder participation in native vegetation management in irrigation areas. Ecol. Manage. Restor. 8, 42–48.
Michler, J.D., Baylisa, K., Arends-Kuenninga, M., Mazvimavi, K., 2016. Conservation Agriculture and Climate Resilience. ICRISAT.
Millar, J., Connell, J., 2010. Strategies for scaling out impacts from agricultural systems change: the case of forages and livestock production in Laos. Agric. Hum. Values 27, 213–225.
Moyo, S., Yeros, P., 2005. Reclaiming the Land: The Resurgence of Rural Movements in Africa, Asia and Latin America. Zed Books.
Nigussie, Z., Tsunekawa, A., Haregeweyn, N., Adgo, E., Cochrane, L., Floquet, A., Abele, S., 2018. Applying Ostrom's institutional analysis and development framework to soil and water conservation activities in north-western Ethiopia. Land Use Policy 71, 1–10.
Nkemelang, T., New, M., Zaroug, M., 2018. Temperature and precipitation extremes under current, 1.5° C and 2.0° C global warming above pre-industrial levels over Botswana, and implications for climate change vulnerability. Environ. Res. Lett. 13, 065016.
Nkonya, E., Jawoo, K., Edward, K., Timothy, J., et al., 2018. Climate risk management through sustainable Land and Water management in Sub-Saharan Africa. In: Lipper, L. (Ed.), Climate Smart Agriculture. Natural Resource Management and Policy.
North, D.C, 1990. Institutions, Institutional Change and Economic Performance. Cambridge university press, Cambridge.
Nyikahadzoi, K., Siziba, S., Mango, N., Mapfumo, P., Adekunhle, A., Fatunbi, O., 2012. Creating food self reliance among the smallholder farmers of eastern Zimbabwe: exploring the role of integrated agricultural research for development. Food Security 4, 647–656.
Nyong, A., Adesina, F., Elasha, B.O., 2007. The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. Mitig. Adapt. Strat. Glob. Change 12, 787–797.
Ojango, J.M., Audho, J., Oyieng, E., Recha, J., Muigai, A., 2015. Sustainable Small Ruminant Breeding Program for Climate-Smart Villages in Kenya, CCAFS Working Paper 127. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), Copenhagen, Denmark.
Ojiem, J.O., De Ridder, N., VanLauwe, B., Giller, K.E., 2006. Socio-ecological niche: a conceptual framework for integration of legumes in smallholder farming systems. Int. J. Agric. Sustain. 4, 79–93.
Ostrom, E., 1990. Governing the Commons: the Evolution of Institutions for Collective Action. Cambridge University Press, UK, Cambridge.
Ostrom, E., Gardner, R., Walker, J., Walker, J., 1994. Rules, Games, and Common-Pool Resources. University of Michigan Press.
Pachico, D., Fujisaka, 2004. Scaling up and Out: Achieving Widespread Impact Through Agricultural Research. CIAT, Cali, Colombia.
Pannell, D.J., Marshall, G.R., Barr, N., Curtis, A., Vanclay, F., Wilkinson, R., 2006. Understanding and promoting adoption of conservation technologies by rural landholders. Aust. J. Exp. Agric. 46, 1407–1424.
Porter, J.R., Xie, L., Challinor, A.J., Cochrane, K., Howden, S.M., Iqbal, M.M., Lobell, D.B., Travasso, M.I., 2014. Food security and food production systems. In: Field, ea.E. (Ed.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, USA, pp. 485–533.
Qureish, N., Amadou, N., Bashir, J., Mary, N., 2001. Scaling up adoption and impact of agroforestry technologies: experiences from western Kenya. Dev. Pract. 11, 509–523.
Raheem, N., 2014. Using the Institutional Analysis and Development (IAD) framework to analyze the acequias of El Río de las Gallinas, New Mexico. Soc. Sci. J. 51, 447–454.
Raymond, L., Weldon, S.L., 2013. Climate Change Policy and Informal Institutions. Purdue University, USA.
Ringler, C., Nkonya, E., 2012. Sustainable land and water management policies. In: Stewart, R.L., B (Eds.), Soil Water and Agronomic Productivity. Advances in soil science. CRC Press Taylor Francis Group, New York, pp. 523–538.
Rogers, E.M., 2003. Diffusion of innovations. Free Pres, New York.
Roothaert, R., Kaaria, S., 2004. Issues and strategies for going to scale: a case study of the forages for smallholders project in the Philippines. In: Pachio, D., Fujisaka, S. (Eds.), Scaling up and Out: Achieving Widespread Impact Through Agricultural Research, pp. 71–92.
Rosset, P.M., Martínez-Torres, M.E., 2012. Rural social movements and agroecology: context, theory, and process. Ecol. Soc. 17.
Rosset, P.M., Machín Sosa, B., Roque Jaime, A.M., Ávila Lozano, D.R., 2011. The Campesino-to-Campesino agroecology movement of ANAP in Cuba: social process methodology in the construction of sustainable peasant agriculture and food sovereignty. J. Peasant Stud. 38, 161–191.
Ruben, R., Pender, J., 2004. Rural diversity and heterogeneity in less-favoured areas: the quest for policy targeting. Food policy 29, 303–320.
Schlenker, W., Lobell, D.B., 2010. Robust negative impacts of climate change on African agriculture. Environ. Res. Lett. 5, 014010.
Schleussner, C.-F., Lissner, T.K., Fischer, E.M., Wohland, J., Perrette, M., Golly, A., Rogelj, J., Childers, K., Schewe, J., Frieler, K., 2016. Differential climate impacts for policy-relevant limits to global warming: the case of 1.5 C and 2 C. Earth Syst. Dyn. 7, 327–351.
Scoones, I., Thompson, J., 1994. Beyond Farmer First: Rural People's Knowledge, Agricultural Research, and Extension Practice. Intermediate Technology Publications, London.
Setimela, P.S., Lunduka, R., Zaman-Allah, M., Ndoro, O., Cairns, J.E., 2017a. Performance of Elite Drought Tolerant Maize Varieties Eastern and Southern Africa. Season 2015–16. CIMMYT, Zimbabwe, Harare, Zimbabwe.
Setimela, P.S., Magorokosho, C., Lunduka, R., Gasura, E., Makumbi, D., Tarekegne, A., Cairns, J.E., Ndhlela, T., Erenstein, O., Mwangi, W., 2017b. On-farm yield gains with stress-tolerant maize in eastern and southern Africa. Agron. J. 109, 406–417.
Siziba, S., Nyikahadzoi, K., Nyemeck, J.B., Diagne, A., Adewale, A., Oluwole, F., 2013. Estimating the impact of innovation systems on maize yields: the case of Iar4d in southern Africa. Agrekon 52, 83–100.
Snapp, S., Heong, K., 2003. Scaling up and Out. Managing Natural Resources for Sustainable Livelihoods: Uniting Science and Participation. pp. 67–87.
Sohail, M., Cavill, S., 2008. Accountability to prevent corruption in construction projects. J. Constr. Eng. Manage. 134, 729–738.
Steenwerth, K.L., Hodson, A.K., Bloom, A.J., Carter, M.R., Cattaneo, A., Chartres, C.J., Hatfield, J.L., Henry, K., Hopmans, J.W., Horwath, W.R., Jenkins, B.M., Kebreab, E., Leemans, R., Lipper, L., Lubell, M.N., Msangi, S., Prabhu, R., Reynolds, M.P., Sandoval, S., Solis, W.M., Sischo, M., Springborn, P., Tittonell, S.M., Wheeler, S.J., Vermeulen, E.K., Wollenberg, L.S., Jarvis, L.E., Jackson, L.E., 2014. Climate-smart agriculture global research agenda: scientific basis for action. Agric. Food Security 3, 11.
Stur, W.W., Horne, P.M., Gabunada, F.A., Phengsavanh, P., Kerridge, P., 2002. Forage options for smallholder crop-animal systems in Southeast Asia: working with farmers to find solutions. Agric. Syst. 71, 75–98.
Swallow, B.M., Garrity, D.P., Van Noordwijk, M., 2002. The effects of scales, flows and filters on property rights and collective action in watershed management. Water Policy 3, 457–474.
Swaminathan-H, S.D.B.-R., et al., 2010. Impact of access to credit on labor allocation patterns in Malawi. World Dev. 38, 555–566.
Teklewold, H., Kassie, M., Shiferaw, B., 2013. Adoption of multiple sustainable agricultural practices in rural Ethiopia. J. Agric. Econ. 64, 597–623.
Thorlakson, T., Neufeldt, H., 2012. Reducing subsistence farmers' vulnerability to climate change: evaluating the potential contributions of agroforestry in western Kenya. Agric. Food Security 1, 15.
Thornton, P.K., Herrero, M., 2010. Potential for reduced methane and carbon dioxide emissions from livestock and pasture management in the tropics. Proc. Natl. Acad. Sci. 107, 19667–19672.
Upton, C., 2012. Adaptive capacity and institutional evolution in contemporary pastoral societies. Appl. Geogr. 33, 135–141.
USAID, 2014. Scaling up the Adoption and Use of Agricultural Technologies. Global learning and evidence exchange (GLEE) USAID, Bangkok, Thailand.
Uvin, P., 1995. Fighting hunger at the grassroots: paths to scaling up. World Dev. 23, 927–939.
Valentinov, V., 2007. Why are cooperatives important in agriculture? An organizational economics perspective. J. Inst. Econ. 3, 55–69.
Verhofstadt, E., Maertens, M., 2014. Smallholder cooperatives and agricultural performance in Rwanda: do organizational differences matter? Agric. Econ 45, 39–52.
Wanglin, M., Awudu, A., 2015. Does cooperative membership improve household welfare? Evidence from apple farmers in China. Food Policy 58, 94–102.
Westermann, O., Förch, W., Thornton, P.K., 2015. Reaching More Farmers: Innovative Approaches to Scaling up Climate Smart Agriculture., CCAFS Working Paper No 135. CGIAR Research Program on Climate Change. Agriculture and Food Security CCAFS, Copenhagen, Denmark.

Westermann, O., Förch, W., Thornton, P., Jana, K., Laura, C., Bruce, C., 2018. Scaling up agricultural interventions: case studies of climate-smart agriculture. Agric. Syst. 165, 283–293.
Wigboldus, S., Leeuwis, C., 2013. Towards Responsible Scaling up and Out in Agricultural Development: An Exploration of Concepts and Principles. Centre for Development Innovation. Wageningen UR; Knowledge, Technology Innovation Group, Wageningen UR.
Winowiecki, L., Läderach, P., Mwongera, C., Twyman, J., Mashisia, K., Okolo, W., Eitzinger, A., Rodriguez, B., 2015. Increasing food security and farming system resilience in East Africa through wide-scale adoption of climate-smart agricultural practices. Harvard Dataverse V8.
World Bank, 2001. World Development 2000/2001: Attacking Poverty. Oxford University Press, New York.
World Bank, 2003. Scaling-up the Impact of Good Practices in Rural Development, A Working Paper to Support Implementation of the World Bank's Rural Development Strategy. World Bank, Washington, DC.
Zseleczky, L., Yosef, S., 2014. Are shocks becoming more frequent or intense? In: Shenggen, F., Rajul, P.-L., Sivan, Y. (Eds.), Resilience for Food and Nutrition Security, Washington DC, pp. 9–17.